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[Description]

[Power semiconductor switch] POWER SEMICONDUCTOR SWITCH

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The present invention relates to an IGBT (Insulated Gate Bipolar Transistor) which is suitable for forming bidirectional switches.

10 Background of the Invention:Field of the Invention:

The invention lies in the field of semiconductor circuits.

15 Commercially available IGBTs can be used to construct bidirectional switches which are used e.g. in converters, by each IGBT being connected in series with a diode. In this case, the forward direction of the diode corresponds to the switchable current direction  
20 of the IGBT. This circuit therefore effects blocking in the reverse direction. However, high on-state losses have to be accepted with this. US 5,608,237 describes a bidirectional semiconductor switch comprising IGBTs in which IGBT structures are formed on two mutually  
25 opposite main sides of a semiconductor body. The dimensioning of such proposals for bidirectionally blocking switches is in each case chosen in such a way as to produce an NPT component (Non Punch Through). A triangular field profile builds up in the component  
30 under blocking loading. Other symmetrically blocking components such as e.g. thyristors or GTOs likewise have a non-punch-through dimensioning. That requires the component to have a large thickness and thus increases the switching and on-state losses in relation  
35 to the thinner punch-through dimensioning.

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[It is an object of the present invention to specify a simply designed switch which can block high voltages in both directions. This object is achieved by means of the component having the features of claim 1. Refinements emerge from the dependent claim.] The invention provides a power semiconductor switch that overcomes the hereinafore-mentioned disadvantages of the heretofore-known devices of this general type and that is simpler in construction and that can block high voltages in both directions.

Summary of the Invention:

In the case of the component according to the invention, a conventional structure of a power semiconductor switch, e.g. of an IGBT, is provided with an additional buffer layer on the source side and dimensioned in such a way that, in an operating state in which the component effects blocking, at least in a range of high electrical voltages which are applied to source and drain, a space charge zone produced in the semiconductor body extends as far as the respective buffer layer in accordance with a punch-through dimensioning. By virtue of the buffer layers present on both sides, the advantage of punch-through dimensioning (small thickness of the component) is combined with the advantage of non-punch-through dimensioning (possibility of symmetrical blocking capability).

[The component according to the invention is described in more detail below using the example illustrated in cross section in the figure.]

Brief Description of the Drawings:

FIG. 1 is a diagrammatic cross-sectional view of a semiconductor structure according to the invention; and

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FIG. 2 is graph showing a profile of the electric field against the vertical direction of the structure of FIG. 1 for different polarities.

5 [A detail from an IGBT structure is illustrated in cross section on the right-hand side of the figure. A first base region 1 is essentially formed by the semiconductor body provided with a basic doping. This basic doping is preferably a doping for weak n-type  
10 conductivity. In accordance with an IGBT structure known per se, a second base region 4 of opposite sign and emitter regions 3, 5 are present. The sequence of these regions has conductivities having alternating signs in the vertical direction. In the second base  
15 region 4, which is formed in a manner extending as far as the top side of the semiconductor body, a channel is formed on said top side, which channel can be controlled by means of a gate electrode G applied above it and preferably isolated from it by a dielectric. The  
20 second base region 4 is preferably formed as a p-conducting doped well in the n<sup>-</sup>-conducting doped semiconductor body. Situated within this well is the region 5 doped oppositely thereto (in this example n-conducting), said region being connected to the  
25 source contact S, which also makes contact with the second base region 4. Situated on the rear side of the component is a further doped region 3, which, as emitter region, is doped oppositely to the first base region 1 and is provided with a drain contact D. In  
30 accordance with a punch-through dimensioning known per se, the thickness of the semiconductor body is chosen to be smaller than in IGBTs with non-punch-through dimensioning, and a buffer layer 2 whose conductivity has the same sign as that of the first base region 1 is  
35 arranged between the first base region 1 and the region provided with the drain contact (p-type emitter). This buffer layer 2 is preferably doped with a dose of  $1 \cdot 10^{12} \text{ cm}^{-2}$  to  $4 \cdot 10^{12} \text{ cm}^{-2}$  (integral over the doping

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profile). In the blocking operating state of the component, in contrast to the conventional layer structure with buffer layer, the electric field for the most part falls in the first base region 1. A typical  
5 profile of the electric field in the vertical direction of the component is illustrated on the left-hand side of the figure for the case where the drain terminal is positive relative to the source terminal (solid curve in the  $\gamma$ -E diagram).]

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Description of the Preferred Embodiments:

Referring now to the figures of the drawings in detail and first, particularly to FIG. 1 thereof, there is shown a cross-sectional detail from an IGBT structure.

15 A first base region 1 is essentially formed by the semiconductor body provided with a basic doping. The basic doping is preferably a doping for weak n-type conductivity. In accordance with conventional IGBT structure, also present are a second base region 4 of  
20 opposite sign and emitter regions 3, 5. The sequence of these regions has conductivities having alternating signs in the vertical direction. In the second base region 4, which is formed in a manner extending as far as the top side of the semiconductor body, a channel is  
25 formed on the top side, which channel can be controlled by a gate electrode G applied above the channel and preferably isolated from the channel by a dielectric. The second base region 4 is preferably formed as a p-  
30 conducting doped well in the n<sup>-</sup>-conducting doped semiconductor body. Situated within the well is the region 5 doped oppositely thereto (in the example shown, the region 5 is n-conducting). The emitter region 5 is connected to the source contact S. The source contact S also makes contact with the second  
35 base region 4.

Situated on the rear side of the component is a further doped region 3, which, as an emitter region, is doped

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oppositely to the first base region 1 and is provided with a drain contact D. In accordance with a conventional punch-through dimensioning, the thickness of the semiconductor body is chosen to be smaller than  
5 in IGBTs with non-punch-through dimensioning, and a buffer layer 2 whose conductivity has the same sign as that of the first base region 1 is disposed between the first base region 1 and the region provided with the drain contact (p-type emitter). The buffer layer 2 is  
10 preferably doped with a dose of  $1 \cdot 10^{12} \text{ cm}^{-2}$  to  $4 \cdot 10^{12} \text{ cm}^{-2}$  (integral over the doping profile). In the blocking operating state of the component, in contrast to a conventional layer structure with buffer layer, the electric field for the most part falls in the first  
15 base region 1.

A typical profile of the electric field in the vertical direction of the component is illustrated in FIG. 2 for the case where the drain terminal is positive relative  
20 to the source terminal (solid curve in the y-E diagram).

What is essential to the invention is a further buffer layer 6, which is present between the first base region  
25 1 and the second base region 4 and is doped such that its electrical conductivity has the same sign as that of the first base region 1 (basic doping of the semiconductor body). This further buffer layer 6, which is n-conducting in this example, is doped so highly  
30 (most preferably with a dose of  $1 \cdot 10^{12} \text{ cm}^{-2}$  to  $4 \cdot 10^{12} \text{ cm}^{-2}$ ) that, in the event of polarity reversal of the voltage between drain and source, a profile of the electric field in the vertical direction of the component is produced which, in principle, corresponds  
35 to the broken curve depicted in the diagram on the left-hand side of the figure. To an extent, the punch-through case for the opposite direction is present here, with the result that this component also blocks

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high voltages in both directions. The blocking operating state is changed over, in a manner known per se, into the operating state open from source to drain, by means of the control of the channel via the gate electrode. Therefore, according to the invention, a component is present which constitutes a switch in a current direction and blocks the current in the opposite direction up to high voltages.

10 The basic doping of the semiconductor body is preferably chosen to be somewhat lower than is otherwise customary (e.g., for 1200 V IGBTs, 90  $\Omega\text{cm}$  instead of 60  $\Omega\text{cm}$ ). The thickness and the magnitude of the doping in the first base region 1 and the two  
15 buffer layers 2, 6 must be accurately dimensioned; in the case of an excessively high doping and/or thickness of the layers, a premature breakdown takes place on account of the avalanche multiplication of the charge carriers (avalanche effect) and, in the case of an  
20 excessively low doping of the buffer layers, a breakdown takes place on account of punch-through of the blocked PNP transistor. In the case of correct dimensioning, which can easily be found using the customary procedures for the respective exemplary  
25 embodiment, it is possible to reduce the thickness of the component. In addition, the further buffer layer 6 under the p-conducting doped well in the semiconductor body brings about an elevation of the charge carrier density in this region, with the result that the  
30 switching losses are reduced and an improvement by approximately 30 - 40% with the on-state losses remaining the same is possible. As a result, it is possible to realize a symmetrically blocking 1200 V IGBT, and likewise symmetrically blocking thyristors or  
35 GTOS.

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[Patent Claims] I claim:

1. A component having a semiconductor body, in which  
four doped regions (1, 3, 4, 5) whose  
conductivities have alternating signs are formed  
one above the other between two main sides, of  
which regions  
one region, as first base region (1), has a low  
basic doping of the semiconductor body, and  
a further region, whose conductivity has an  
opposite sign to that of the former region, is  
formed as second base region (4) in a manner  
extending as far as one of the main sides and is  
provided with a gate electrode (G), which is  
present on said main side, in such a way that a  
channel formed in the second base region can be  
controlled, and  
the two remaining regions (3, 5) are provided with  
a source contact (S), which also makes contact  
with the second base region and is applied on the  
same main side as the gate electrode, or  
respectively with a drain contact (D),  
in which case a further region, which is doped  
such that its conductivity has the same sign as  
the first base region, is present as buffer layer  
(2) between the first base region (1) and the  
region provided with the drain contact (D), and  
the first base region (1) is dimensioned in such a  
way, and the magnitude of the doping of the buffer  
layer (2) is chosen in such a way, that, in an  
operating state in which the component effects  
blocking in the direction from the source contact  
toward the drain contact, at least in an envisaged  
range of applied electrical voltages, a space  
charge zone present in the first base region is

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formed in a manner extending at least as far as the buffer layer (2),

wherein

5 a further buffer layer (6), which is doped such that its conductivity has the same sign as the first base region, is present between the first base region (1) and the second base region (4), and

10 the magnitude of the doping of the further buffer layer (6) is chosen in such a way that the component effects blocking in the direction from the drain contact toward the source contact in an envisaged range of opposite applied electrical voltages.

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2. The component as claimed in claim 1,

in which the magnitude of the doping of the further buffer layer (6) is chosen in such a way that, in an operating state in which the component effects blocking in the direction from the drain contact toward the source contact, at least in an envisaged range of applied electrical voltages, a space charge zone present in the first base region (1) is formed in a manner extending at least as far as the further buffer layer (6).

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